

# Technique of production of argon-37 at proton cyclotron and detector for measurements

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## Abstract

The technology of production of the isotope Ar-37 at proton cyclotron is developed. It is based on irradiation of the Cl-37 target with the protons of energy of a few a MeV. The example of production of tiny amount of Ar-37 is described and discussed. The detectors to measure the intensity of the sample is discussed.

## 1 Introduction

The  $^{37}\text{Ar}$  isotope is very important in different fields of physics. It decays by 100% electron capture (EC)  $3/2^+ \rightarrow 3/2^+$  transition to the ground state of the stable nuclide  $^{37}\text{Cl}$ . The decay scheme is complete as there no excited levels of  $^{37}\text{Cl}$  below the EC decay energy  $Q^+=813.87$  keV [1]. Due to the monoenergetic neutrino lines (811 and 813 keV) and the absence of the nuclear  $\gamma$ -radiation it is suitable to test neutrino detectors. In 1988 Haxton proposed to employ the  $^{37}\text{Ar}$  source to calibrate radiochemical detectors of solar neutrinos [2], especially gallium based one ([3], [4]). Approximately 1 MCi source was produced [5] according to that proposal and the SAGE detector was successfully calibrated [6]. Another perspective possible usage of the isotope is a calibration of low energy electron detectors by means of the low energy Auger electron and X-ray emission. It can be used in the experiments aiming to search for a possible sterile neutrino admixture in the  $\beta$ -spectra of different isotopes. In particular, the experiments with tritium [7] are possible employers of the  $^{37}\text{Ar}$  source.

## 2 Technology of production by neutron irradiation

The 1 MCi  $^{37}\text{Ar}$  used for the gallium detector calibration neutrino source was manufactured by irradiating a piece of pressed calcium oxide in the fast breeder reactor BN-600 in Russia [5]. The technology was based on the  $^{40}\text{Ca}(\text{n},\alpha)^{37}\text{Ar}$  reaction. The fast neutron flux was measured by an organic scintillator [8]. A special facility was build [9] in order to extract the gaseous  $^{37}\text{Ar}$  sample from the CaO target. An obvious disadvantage of the method is that after neutron irradiation there is a lot of  $^{39}\text{Ar}$  - in [5] they report the contamination to be of 0.34% of the gas volume fraction.

## 3 Technology of production by proton irradiation

The reaction  $^{37}\text{Cl}(\text{p},\text{n})^{37}\text{Ar}$  looks to be able to produce much more pure samples of  $^{37}\text{Ar}$ . One of the first usage of the method was published in [10]. We have developed a technique of preparation of the target based on a KCl film. The target is a Nb foil  $20\times 10\times 1$  mm with a spot of thin KCl film deposited at the foil in vacuum. The spot is roughly circular with the area of  $1.5\text{ cm}^2$ . The thickness of the film is  $100\text{ }\mu\text{m}$ , the mass of the KCl is about 30 mg. The target was firstly irradiated at the Moscow State University proton cyclotron of the Institute of Nuclear Physics; the energy of protons was  $E_p=7\text{ MeV}$  and the current was  $I_p=2\text{ }\mu\text{A}$ .

The calculation of an expected activity of  $^{37}\text{Ar}$  was done without taking into account of ionization energy loss. The maximal expected value of the intensity may be estimated as

$$N = N_p \sigma n = \frac{I_p \Delta t}{e} \sigma \rho d \frac{N_A}{A}$$

Here  $N$  is the number of  $^{37}\text{Ar}$  atoms produced in the reaction;  $e$  is the electron charge,  $1.6\cdot 10^{19}\text{ Ql}$ ;  $N_p$  is the number of protons bombarded the target during irradiation for the time period  $\Delta t$  and the current  $I_p$ ;  $\sigma$  is the cross-section of the reaction;  $\rho$ ,  $d$  is the density and thikness of the target;  $A$  is the atomic number of the target;  $N_A$  is the Avogadro constant,  $6.02\cdot 10^{23}\text{ }\frac{1}{\text{mol}}$ .

An isotope  $^{37}\text{Ar}$  is produced in the reaction  $^{37}\text{Cl}(\text{p},\text{n})^{37}\text{Ar}$  that has a cross-section of  $\approx 0.5$  barn at the proton energy  $E_p=7\text{ MeV}$ . The target KCl has the molar mass of  $74.5\text{ }\frac{\text{g}}{\text{mol}}$  and the density of  $1.98\text{ }\frac{\text{g}}{\text{cm}^3}$ . Taking into account the 24.2% abundance of  $^{37}\text{Cl}$  in the natural target we may expect for 2 hours

irradiation  $N = 3.5 \cdot 10^{11}$  atoms of  $^{37}\text{Ar}$ . Because half-life of  $^{37}\text{Ar}$  is 35 days it corresponds to  $5.7 \cdot 10^4$  Bq of the intensity immediately after end of bombardment. The real sample was obtained after 2-hours irradiation and filling a proportional counter at special system [11]. The proportional counter was made according to the technology described in [12]. The result of the intensity measurement was about  $5.3 \pm 0.6$  Bq that is in good agreement with the calculation.

## 4 Conclusion

The technology of production of pure  $^{37}\text{Ar}$  based on irradiation the KCl target with protons with an energy of a few MeV is developed and tested for small amount of source. The proportional counter is most suitable detector to measure a tiny amount of  $^{37}\text{Ar}$ .

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